

Chapter 3

Alumina Production

The domestic alumina production (bauxite refining) industry consists of five facilities that, as of September 1989, were active and reported generating a special waste from mineral processing: red and brown muds from bauxite refining. The information included in this chapter is provided in additional detail in the supporting public docket for this report.

3.1 Industry Overview

Bauxite refineries produce alumina (Al_2O_3), which is used primarily as a feedstock for the aluminum reduction industry. Four of the facilities are operated by major aluminum producers, two by Alcoa, and one each by Reynolds and Kaiser. The fifth facility is operated by Ormet, which produced only about 1 percent of the total reported 1988 alumina production. Kaiser Aluminum is ultimately owned by MAXXAM Inc. of Los Angeles;¹ Ormet, owned by Ohio River Associates in 1988, is currently owned by Oralco Management Services Inc.

The dates of initial operation for these five facilities range from 1952 to 1959, with the individual plants having an average age of approximately 33 years. All of the facilities have undergone modernization, with the first in 1965 and the latest in 1986.² The locations and ore sources of the five facilities are presented in Exhibit 3-1. Total annual production capacity for the domestic bauxite refining industry, as reported by the facilities, is approximately 4,900,000 metric tons. For the five facilities, the 1988 average capacity utilization rate was 83.5 percent. Excluding the Ormet facility with an 8.9 percent 1988 annual capacity utilization rate, the rate for the sector is 91.7 percent. The total reported 1988 production of alumina was 4,086,000 metric tons.³

Strong demand for primary aluminum and elevated aluminum prices have led to steadily increasing consumption of domestic and imported bauxite and continued increases in alumina production in the U.S. since 1986.⁴ In order to meet the growing demand for alumina, bauxite refineries have averaged over 90 percent capacity utilization over the past two years. Recently, expansion in bauxite refining capacity has been focused outside of the U.S. It is likely that this trend will continue in the future, with major capacity additions likely to occur in Canada and the Middle East.⁵ In addition, new plants using new technology may have to be built to produce alumina from the numerous non-bauxitic materials, including clay, coal waste, and oil shales, that are good potential sources of alumina.⁶ Development of such technology would reduce U.S. dependence on bauxite imports, which comprised approximately 95 percent of the total 1989 U.S. consumption of bauxite.⁷

¹ MAXXAM Inc. is the parent of MAXXAM Group, Inc., which owns Kaiser Tech Limited, the immediate owner of Kaiser Aluminum and Chemical Corporation.

² Alcoa, Kaiser, Ormet, and Reynolds, 1989. Company responses to "National Survey of Solid Wastes from Mineral Processing Facilities," 1989.

³ Ibid.

⁴ Luke H. Baumgardner, U.S. Bureau of Mines, "Bauxite," Mineral Commodity Summaries, 1989 Ed., p. 23.

⁵ John W. Moberly, "Aluminum: Capacity Rise Stabilizes Price; 121st Annual Survey and Outlook," E&MJ, March 1990, p. 41.

⁶ Patricia A. Plunkert, U.S. Bureau of Mines, "Bauxite," Mineral Commodity Summaries, 1990 Ed., p. 29.

⁷ Ibid., p. 28.

Exhibit 3-1 Bauxite Refineries^(a)

Owner	Location	Ore Source (1982)
ALCOA	Bauxite, AR ^(b)	U.S. (Bauxite, AR) ^(c)
ALCOA	Point Comfort, TX	(Confidential)
Kaiser	Gramercy, LA	Jamaica ^(d)
ORMET	Burnside, LA	Sierra Leone, Brazil, Guyana ^(e)
Reynolds	Gregory, TX	Australia, Jamaica, Brazil, Guinea ^(e)

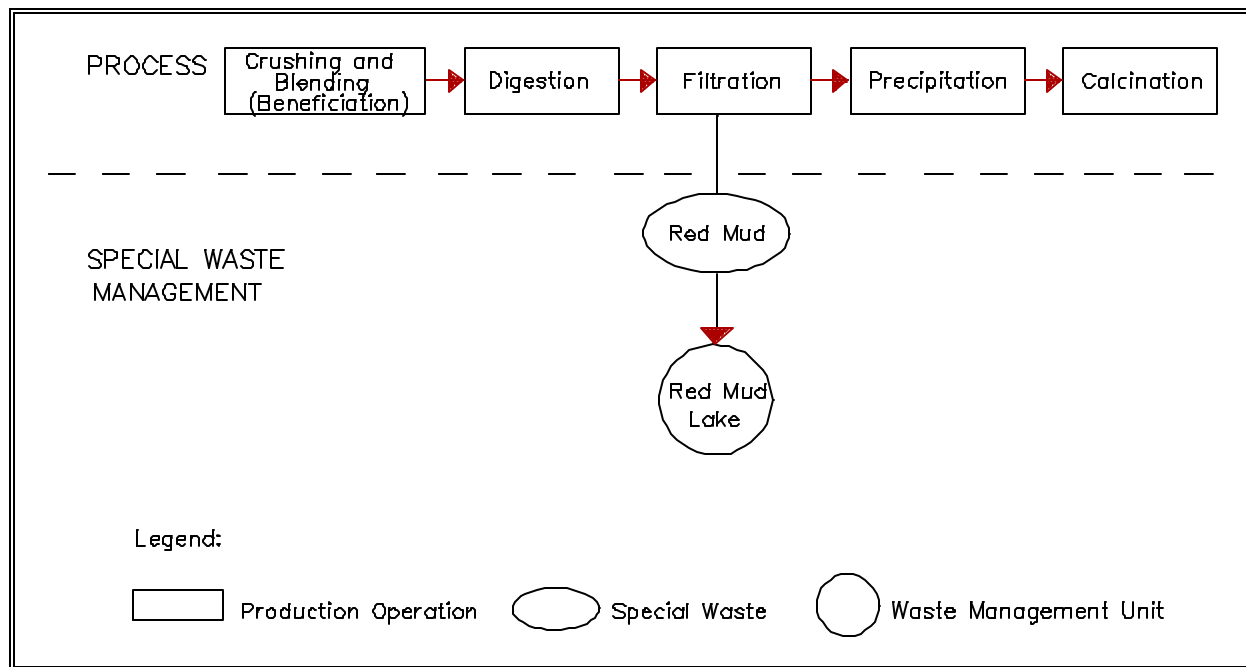
- (a) According to BOM sources, VIALCO, an affiliate of Oralco Management Services Inc., plans to restart operation of its Alumina plant at St. Croix, U.S. Virgin Islands.
- (b) According to BOM sources, Alcoa announced the permanent closure of its Bauxite, AR, plants on June 7, 1990.
- (c) Environmental Protection Agency, 1984. Overview of Solid Waste Generation, Management, and Chemical Characteristics in the Bauxite Refining and Primary Aluminum Industry. Prepared by Radian Corporation for U.S. EPA, Office of Solid Waste, Washington, D.C., November 1984.
- (d) Kaiser, 1988. Personal communication with Kaiser representatives.
- (e) Bureau of Mines commodity specialist, June 27, 1990.

The production of alumina from bauxite ore generally follows five steps, as shown in Exhibit 3-2.⁸ First, the bauxite ore is crushed and screened, and then mixed with a caustic alkaline solution (NaOH). The slurried ore is then routed to digesters, where the aluminum is heated and solubilized as sodium aluminate ($\text{Na}_2\text{Al}_2\text{O}_3$). In the third step, the solution is cooled (from nearly 500°F to about 200°F) and purified. Sand (particles above 100 microns) is removed in a settling tank or cyclone and sent to disposal. Iron oxide, silica, and other undigested portions of the ore (i.e., the special waste, known collectively as red mud) are also removed in settling, thickening, and filtration units, and sent to treatment and disposal units. The fourth refining step is the precipitation of the cooled and purified aluminum hydroxide using sodium hydroxide seed crystals. The precipitate is filtered, then concentrated by evaporation; the resulting intermediate product is a hydroxide filter cake. The fifth and final step is the calcination of the hydroxide filter cake to produce anhydrous alumina. If hydrate is the desired final product, the hydroxide filter cake may be dried at lower temperatures than those employed for calcining.

3.2 Waste Characteristics, Generation, and Current Management Practices

⁸ Environmental Protection Agency, 1984. Overview of Solid Waste Generation, Management, and Chemical Characteristics in the Bauxite Refining and Primary Aluminum Industry. Prepared by Radian Corporation for U.S. EPA, Office of Solid Waste, Washington, D.C., November 1984.

Exhibit 3-2
Alumina Production



Red and brown muds are precipitated from a caustic suspension of sodium aluminate in a slurry and routed to large on-site surface impoundments known as red and brown mud lakes. In these lakes, the red and brown muds settle to the bottom and the water is removed, treated, and either discharged or reused. The muds are not removed, but are accumulated and disposed in place. The muds dry to a solid with a very fine particle size (sometimes less than 1 μm).

Red muds from bauxite refining are generated at four facilities⁹. The fifth facility, Alcoa in Bauxite, Arkansas, generates a residual that is different in color and is commonly called brown mud. The only difference in the operations generating the two varieties of mud is that red muds at Alcoa/Bauxite are sintered and leached to recover additional sodium aluminate, which changes the color of the material but does not substantially change the chemical characteristics of the waste. Therefore, for purposes of this report, the waste generated at all five facilities, including the brown muds, will be referred to as red muds.

Red muds contain significant amounts of iron (20 to 50 percent), aluminum (20 to 30 percent), silicon (10 to 20 percent), calcium (10 to 30 percent), and sodium (10 to 20 percent). Red muds may also contain trace amounts of elements such as barium, boron, cadmium, chromium, cobalt, gallium, vanadium, scandium, and lead, as well as radionuclides. The types and concentrations of minerals present in the muds depend on the composition of the ore and the operating conditions in the digesters.

Using available data on the composition of red muds, EPA evaluated whether this waste exhibits any of the four hazardous waste characteristics: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Data are available on the concentrations of all eight inorganic EP constituents in four samples of red muds from three of the five facilities of interest. Based on available information and professional judgment, EPA does not believe that red muds

⁹ In the April 17, 1989 proposal to reinterpret the scope of the mining waste exclusion, EPA indicated that it "considers pisolites to be a component of red muds" (54 FR 15335). In the final rule (see 54 FR 36592, September 1, 1989), however, the scope of beneficiation activities was revised such that pisolites are considered a waste from beneficiation rather than processing. Consequently, pisolites are not within the scope of this report.

exhibit any of the characteristics of hazardous waste. In fact, the concentrations of all EP constituents (except selenium) in the leachate are at least two orders of magnitude below the EP regulatory levels; the maximum concentration of selenium in the EP extract is approximately 0.3 times the EP regulatory level.

Non-confidential waste generation rate data were reported for red muds by all five bauxite refining facilities. The aggregate industry-wide generation of red mud wastes by the five facilities was approximately 2.8 million metric tons in 1988, yielding a facility average of nearly 564,000 metric tons per year. Reported annual generation rates ranged from 26,000 to 1.2 million metric tons per facility, though the facility generating the least waste, Ormet/Burnside, produced very little alumina, accounting for only about 1 percent of domestic production. The next lowest reported annual generation rate was 190,000 metric tons. The sector-wide waste-to-product ratio was 0.69 in 1988; waste-to-product ratios for individual facilities ranged from 0.40 to 1.05.

The impoundments that receive the muds typically have a surface area of between 44.6 and 105.3 hectares (110 and 260 acres), although one impoundment is 10.1 hectares and another is almost 1,300 hectares. The depth of the impoundments range from 1 to 16 meters (3 to 52 feet), with an impoundment average of 7 meters. As of 1988, the quantity of muds accumulated on-site at the 5 facilities ranged from 500,000 to 22 million metric tons per facility, with an average of 9.7 million metric tons per facility.

3.3 Potential and Documented Danger to Human Health and the Environment

This section addresses two of the study factors required by §8002(p) of RCRA: (1) potential danger (i.e., risk) to human health and the environment; and (2) documented cases in which danger to human health or the environment has been proved. Overall findings regarding the hazards associated with red muds are provided after these two study factors are discussed.

3.3.1 Risks Associated with Red Mud

Any potential danger to human health and the environment from red muds depends on the presence of toxic constituents in the muds that may pose a risk and the potential for exposure to these constituents.

Constituents of Potential Concern

EPA identified chemical constituents in red muds that may pose a risk by collecting data on the composition of the waste and evaluating the intrinsic hazard of the mud's chemical constituents.

Data on Red Mud Composition

Data on the composition of red muds are available from industry responses to a RCRA §3007 request in 1989, a 1985 sampling and analysis effort by EPA's Office of Solid Waste (OSW),¹⁰ and a 1982 study by EPA's Office of Radiation Programs (ORP).¹¹ These data identify the concentrations of 13 metals, 7 radionuclides, and 5 anions (fluoride, phosphate, chloride, nitrate, and sulfate) in the mud solids and/or leachate from all 5 facilities that currently generate the muds. Data are only available from EP (not SPLP) leach tests.

Although the data from most of these sources and facilities are generally consistent, there is considerable variability for several constituents. Specifically, reported concentrations of arsenic, chromium, copper, iron, manganese, selenium, and zinc in the mud solids vary by an order of magnitude across facilities, with the concentrations usually being lowest at one facility (which requested that its concentration data be treated as confidential). Similarly, reported

¹⁰ Environmental Protection Agency, 1985. Overview of Solid Waste Generation, Management, and Chemical Characteristics in the Bauxite Refining and Primary Aluminum Reduction Industries, Office of Solid Waste, p. B-1 and B-2.

¹¹ Environmental Protection Agency, 1982. Emissions of Naturally Occurring Radioactivity from Aluminum and Copper Facilities, Office of Radiation Programs, Las Vegas Facility, NV, p. 8.

concentrations of chromium, fluoride, selenium, and chloride in the mud leachate also vary by an order of magnitude across facilities.

As noted above in Section 3.2, the available data indicate that red muds do not exhibit any of the four characteristics of hazardous waste. Nevertheless, EPA further evaluated the potential for red muds to pose a danger to human health or the environment, as described below.

Process for Identifying Constituents of Potential Concern

As discussed in detail in Section 2.2.2, the Agency evaluated the red muds data to determine if the mud or mud leachate contain any constituents that could pose an intrinsic hazard, and to narrow the focus of the risk assessment. The Agency performed this evaluation by first comparing the concentrations of each constituent to screening criteria and then by evaluating the environmental persistence and mobility of any constituents present in concentrations that exceed the criteria. These screening criteria were developed using assumed scenarios that are likely to overestimate the extent to which red mud constituents are released to the environment and migrate to possible exposure points. As a result, this process identifies and eliminates from further consideration those constituents that clearly do not pose a risk.

The Agency used three categories of screening criteria that reflect the potential for hazards to human health, aquatic organisms, and water resources (see Exhibit 2-3). Given the conservative (i.e., overly protective) nature of these screening criteria, contaminant concentrations in excess of the criteria should not, in isolation, be interpreted as proof of the hazard. Instead, exceedances of the criteria indicate the need to evaluate the potential hazards of the waste in greater detail.

Identified Constituents of Potential Concern

Of the 25 constituents analyzed in mud solids, only 3 were determined to be present in the muds in concentrations that exceed the screening criteria.

- Arsenic concentrations in one out of two samples collected from two facilities exceed the chronic ingestion and inhalation screening criteria, by a factor of four. Exceedance of the ingestion criterion suggests that arsenic could pose a cancer risk of greater than 10^{-5} if the muds are incidentally ingested on a routine basis (which could only occur if access to mud impoundments after closure is not restricted and people come into direct contact with the dried muds). Exceedance of the inhalation criterion suggests that, if dust from the muds is blown into the air in a concentration that equals the maximum allowable limit (the National Ambient Air Quality Standard) for particulate matter, chronic inhalation of arsenic could pose a cancer risk greater than 10^{-5} . As discussed in the next section, such large exposures to windblown dust are generally not expected.
- Chromium concentrations in both samples (one each from two facilities) exceed the chronic inhalation screening criterion by as much as a factor of 22. This suggests that if dust from the muds is blown into the air in a concentration that equals the National Ambient Air Quality Standard for particulate matter, chronic inhalation of chromium could cause a cancer risk exceeding 10^{-5} . Again, EPA generally does not expect such large exposures, as explained in the next section.
- Radium-226 concentrations in the mud solids exceed the radiation protection screening criterion by a factor of 1.3. This suggests that red muds could pose a slight radiation risk if they are used in an unrestricted manner (e.g., direct radiation and radon exposures if people were allowed to build homes on the closed impoundment areas).

In addition to these three constituents, the alkaline nature (i.e., high pH) of the muds will limit plant growth on the dried, closed impoundments. Data from EPA's Office of Water show that the supernatant removed from the red mud impoundments has a pH of roughly 11.6.¹² The residual alkali content of the muds that are left in the impoundments makes it difficult to use these impoundment areas for agricultural production.¹³

Of the 18 constituents analyzed in leachate from red muds, only two constituents are present in concentrations that exceed the initial screening criteria. Arsenic concentrations in the leachate exceed the health screening criterion in two out of four samples (from two out of three facilities). The maximum recorded arsenic concentration exceeded the screening criterion by only a factor of three. This suggests that, if the leachate is released to ground water and diluted by only a factor of 10, the resulting concentration of arsenic may pose a cancer risk exceeding 10^{-5} if ingested. The concentration of selenium in the leachate exceeds the water resource damage criterion in one out of four samples (from one out of three facilities). The one high selenium concentration exceeds the criterion by only a factor of three. This suggests that, if the leachate is released to ground water and diluted by a factor of 10 or less, the downgradient concentrations of selenium may exceed the drinking water maximum contaminant level (MCL) for that constituent. While these concentrations of arsenic and selenium exceed the conservative screening criteria, they do not exceed the EP toxicity regulatory levels.

These exceedances of the screening criteria, by themselves, do not demonstrate that the muds pose a significant risk, but rather indicate that the muds could pose a risk under a very conservative, hypothetical set of release, transport, and exposure conditions. To determine the potential for the muds to cause significant impacts, EPA proceeded to the next step of the risk assessment to analyze the actual conditions that exist at the facilities that generate and manage the waste.

Release, Transport, and Exposure Potential

This analysis considers the baseline hazards of red muds as they are managed in impoundments at the five bauxite refining facilities. It does not assess the hazards of off-site use or disposal of the muds because the muds are currently managed only on-site and are not likely to be managed off-site in the near future. In addition, the following analysis does not consider the risks associated with variations in waste management practices or potentially exposed populations in the future because of a lack of data on future conditions. Alternative practices for the management of the muds are discussed in Section 3.5.

Ground-Water Release, Transport, and Exposure Potential

During the operating phase of the red mud lakes, the muds are usually submerged beneath a liquid that can serve as a leaching medium, potentially transporting contaminants to underlying ground water. After the lakes are closed, the liquids are evaporated or removed, and the potential for leaching becomes highly dependent on the extent to which precipitation infiltrates through the mud and into the ground. Based on the leach test data analyzed above, arsenic and selenium are the constituents in red muds that are most likely to leach from the muds in concentrations that exceed the screening criteria. Both arsenic and selenium are persistent and relatively mobile in ground water, and therefore are capable of migrating readily if released.

The potential for leachate from the muds to be released to ground water and cause impacts through that pathway varies according to site-specific conditions, as summarized below:

- At the Burnside, LA facility, the mud impoundment is underlain by recompact local clay. Ground water is very shallow (only 2 meters below the land surface) and the base of the impoundment extends below the water table. The uppermost useable aquifer, however, appears

¹² Environmental Protection Agency, 1984. Development Document for Effluent Limitations Guidelines and Standards, Office of Water, p. 56.

¹³ W.A. Anderson and W.E. Haupin, 1978. Bauxite Refining, Aluminum Company of America, Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley and Sons, NY, p. 142.

to be separated from the base of the impoundment by a distance of roughly 30 meters. The nearest drinking water well appears to be located 90 meters downgradient.

- The conditions at the Gramercy, LA facility are similar to those at the Burnside facility. The only differences are that the impoundments at Gramercy are equipped with a leachate collection system and the nearest drinking water well at Gramercy is farther away, approximately 800 meters downgradient. As discussed in the damage case section of this chapter, elevated concentrations of chloride have been detected in ground water beneath the impoundments. However, the muds do not appear to be an important contributor to this contamination because, based on the Agency's leach test analyses, chloride is a minor constituent of the mud leachate (the maximum chloride concentration measured in the mud leachate was less than one-quarter of the conservative screening criterion).
- The impoundment at the Bauxite, AR facility is underlain by in-situ clay and is equipped with a leachate collection system and bentonite slurry walls. The base of the impoundment appears to be separated from shallow ground water by 15 meters and the uppermost useable aquifer by roughly 30 meters. The earth material separating the impoundment from this useable aquifer is an igneous rock. Ground water in the area of the site is used as a rural domestic water supply, and the nearest drinking water well appears to be located 300 meters downgradient.
- At the Point Comfort, TX facility, the mud impoundment is underlain by in-situ clay, but is not equipped with any other controls. Because the impoundment is 16 meters deep and shallow ground water exists at a depth of 5 meters, the base of the impoundment extends below the water table. The uppermost useable aquifer, however, is over 400 meters below the land surface. This deep aquifer is used as a municipal and commercial/industrial water supply, and the nearest drinking water well appears to be located 1,300 meters downgradient.
- The impoundments at the Gregory, TX facility are underlain by in-situ clay. As for most of the other sites, ground water is shallow and the base of the impoundment extends below the water table. Neither the shallow ground water nor water at greater depths, however, is used for water supply purposes, according to facility personnel.

In summary, laboratory leaching tests show that arsenic and selenium may leach from red muds in concentrations that exceed the screening criteria. Concentrations of these and other constituents under field conditions are, however, expected to be lower due to the alkaline nature of the waste. While the potential for release of constituents to ground water is limited by some type of management controls employed at each site, the bases of most impoundments do extend into the saturated zone and shallow ground-water contamination is therefore possible. However, downward migration of this contamination to useable aquifers is less likely, especially at the Bauxite and Point Comfort facilities, because of hydrogeological conditions. Considering the low concentrations of contaminants in the leachate and the potential locations of drinking water wells near these facilities, the concentrations of any contaminants that migrate into the deeper useable aquifers at the five facilities is expected to be below levels of concern at existing downgradient exposure points.

Surface Water Release, Transport, and Exposure Potential

Constituents of potential concern in the red muds could, in theory, enter surface waters by migration of leachate through ground water that discharges to surface water, or by direct overland (storm water) run-off of dissolved or suspended constituents. As discussed above, only arsenic and selenium are expected to leach from the muds in concentrations above the screening criteria, but even these concentrations are relatively low and are likely to be diluted below levels of concern in all but very small streams. There were no constituents detected in the mud leachate in concentrations that appeared to present a potential threat to aquatic organisms; the arsenic and selenium concentrations are of possible concern from only a health risk standpoint. The high alkalinity of the muds, however, could result in leaching of alkaline water. If the receiving water is not well-buffered, its pH could exceed levels that are protective of aquatic life. Alkaline water also can have low resource value due to its corrosive properties.

The potential for mud contaminants to migrate into surface water and cause impacts is site-specific, based on a number of factors as summarized below:

- At the Burnside facility in Louisiana, the red mud impoundment is equipped with run-on/run-off controls to limit the direct overland flow of mud contaminants, but there are no controls (e.g., liner, leachate collection system, or slurry wall) to prevent contaminants from seeping into surface water via ground water. The facility is only 15 meters from the Panama Canal which feeds into the Blind River. While the Blind River has a moderate to large dilution capacity (the annual average flow is 302 mgd), the Panama Canal's flow is small and cannot readily assimilate large contaminant loads. As discussed in the damage case section of this report, excess process water that has accumulated in red mud impoundments at the site during heavy rainfall events has been discharged to the canal, resulting in high pH excursions. These discharges have occurred only in emergency situations, and the pH excursions appear to be caused by the supernatant liquid discharged from the impoundments, not the muds themselves.
- At the Point Comfort facility in Texas, the on-site impoundment is equipped with run-on/run-off controls, but there are no controls to limit seepage of contaminants via ground water. The facility is located only 15 meters from Lavaca Bay, which contains saltwater. Water in the bay is not used for human consumption, but is withdrawn at a point 270 meters downstream and used for livestock watering.
- On-site impoundments at the Gramercy Works in Louisiana are equipped with run-on/run-off controls and a leachate collection system. The facility is located roughly 110 meters from the Blind River, which has a moderate to large dilution capacity (it is the same river that is near the Burnside facility). Water is withdrawn from the river for human consumption at a point 4,900 meters downstream, but water is not withdrawn for any other uses within 24 km (15 miles).
- The impoundment at the facility in Gregory, Texas is equipped with run-on/run-off controls. The facility is located roughly 60 meters from the Corpus Christi Bay, which contains saltwater that is not used for drinking or any other consumptive use within 24 km (15 miles).
- At the facility in Bauxite, Arkansas, the impoundment is equipped with run-on/run-off controls, a leachate collection system, and a bentonite slurry wall. The facility is located about 300 meters from Hurricane Creek, which has a moderate dilution capacity (its annual average flow is 80 mgd). Water is withdrawn from this creek for human consumption at a point 7 km downstream, but water is not withdrawn for any other uses within 24 km (15 miles).

In summary, the potential for direct overland flow of red mud contaminants to surface water is limited at all five facilities by the use of run-on/run-off controls. Migration into surface water via ground-water seepage, however, may occur at three facilities (at Burnside, Point Comfort, and Gregory) that are close to surface water bodies and do not employ any measures to control leachate migration. (The potential for ground-water contamination to seep into surface water at the other facilities is smaller because of the use of leachate migration controls and the greater distance to surface waters.) Because of the distances to drinking water intakes, the moderate to high flows of the nearby water bodies, and the low concentrations of contaminants expected in the mud leachate, any surface water contamination at the three facilities caused by the muds would probably not pose a health threat. In addition, any migration of mud contaminants into surface water is not likely to pose an ecological threat at any facility because, based on the Agency's leach tests, contaminants do not appear to leach from the muds in concentrations that are potentially harmful to aquatic organisms. While the pH of the leachate could be high, pH excursions in surface waters are more likely to be caused by periodic direct discharges, not the low-level chronic loads that are expected through ground-water discharges.

Air Release, Transport, and Exposure Potential

Because all of the constituents of potential concern are nonvolatile inorganics, red mud contaminants can only be released to air in the form of windblown dust. During the operating phase of the impoundments, the potential for dusting from the muds is virtually non-existent because the muds are submerged beneath liquids. When the impoundments are closed and the muds have dried, there is a potential for particles of the mud to be released to air (none

of the facilities practice any dust suppression/control measures). This is especially true at the facilities in arid areas (Gregory and Point Comfort, Texas) where the muds are less likely to remain moist due to precipitation. The muds dry to a very fine particle size (sometimes less than 1 micrometer) which is highly susceptible to wind erosion. Based on sample analyses of the muds, the only constituents that could pose a threat through the inhalation pathway are arsenic and chromium, and this would only be a threat if dust particles are released from dried impoundments in a high concentration (that equals or exceeds the National Ambient Air Quality Standard for particulate matter). The nearest residence at the Gregory facility is 120 meters away, and the nearest residence at the Point Comfort facility is roughly 400 meters away. Considering these distances and the relatively low concentration of contaminants in the muds, airborne concentrations of arsenic and chromium at the existing residences closest to these facilities are likely to be below levels of concern. Dust could be a problem at these facilities, however, if people were allowed to come into close contact with the muds after closure.

Proximity to Sensitive Environments

None of the bauxite refining facilities within the scope of this analysis are located in or within one mile of karst terrane, a fault zone, the habitat of an endangered species, a National Park, a National Forest, or a National Wildlife refuge. In addition, none of the facilities are located in a wetland, although two facilities are located within one mile of wetlands.

Risk Modeling

Based upon the evaluation of intrinsic hazard and the analysis of factors that influence risk presented above, and upon a comprehensive review of information on documented damage cases (presented in the next section), EPA has concluded that the potential for red muds to impose significant risk to human health or the environment if managed according to current practice is low. Therefore, the Agency has not conducted a quantitative risk modeling exercise for this waste. (See sections 3.3.3 and 3.7 below for further discussion.)

3.3.2 Damage Cases

State and EPA regional files were reviewed in an effort to document the performance of waste management practices for red muds from bauxite refining at the five active facilities and at one inactive bauxite facility.¹⁴ The inactive facility was the Alcoa plant in Bayden, North Carolina. The file reviews were combined with interviews with State and EPA regional regulatory staff. Through these case studies, EPA found documented environmental damages associated with red mud discharges to surface water at one facility: Ormet in Burnside, Louisiana. EPA also found evidence of ground-water contamination at the Gramercy, Louisiana facility, but this appears to be associated with brine muds that are not within the scope of this study.¹⁵

¹⁴ Facilities are considered inactive for purposes of this report if they are not currently engaged in primary mineral processing.

¹⁵ This facility generates brine muds that result from the purification of raw brine (solution mined from Sorrento, Louisiana salt domes) for use in the production of caustic and chlorine.

Ormet in Burnside, Louisiana

Ormet Corporation's Aluminum plant is located south of Baton Rouge in Burnside, on LA Highway 22. The facility is situated near the Mississippi River. The processing unit generating red muds has been operational since 1958.¹⁶

The facility contains four red mud lakes, referred to as Nos. 1, 2, 3, and 4. These impoundments have a combined surface area of 85 hectares (210 acres).¹⁷ Impoundments Nos. 1 and 2 have been inactive since 1984. Impoundment 4 is the most recently constructed of the 4 pits.¹⁸

During heavy rainfall events when excess water has accumulated in closed red mud impoundments 1 and 2, Ormet has discharged to a tributary of the "Panama Canal" on an emergency basis.^{19,20} The Panama Canal flows from east to west along the northern boundary of the facility, through residential areas, and is a source of domestic water in some cases.^{21,22}

Discharge of excess waters has resulted in high pH excursions in some cases. For example, excess water was discharged to the Panama Canal between May 23 and May 27, 1983. Due to improper operation of the neutralization station, combined with communications problems, high pH excursions were not detected until after the discharge event. The excessive pH levels ranged from 9.4 to 10.2 for 4.5 hours on May 23, 1983, and from 9.7 to 9.8 for 7.5 hours on May 24, 1983.²³

Ormet has stated that "the Panama Canal cannot readily assimilate the discharge of excess rainwater from the Red Mud Impoundments." Ormet goes on to state that "flow in the Panama Canal stops on some occasions, and on others actually flows backward because of wind or tidal action."²⁴ The Louisiana Department of Environmental Quality (LADEQ) raised concern over the impact of these discharges on the Panama Canal, and requested that Ormet look into the option of discharging to the Mississippi River.²⁵ The emergency discharges to the Panama Canal have imparted a red color to the canal water, resulting in complaints from local residents.^{26,27} Investigation into this phenomenon led

¹⁶ Ormet. 1989. National Survey on Solid Wastes from Mineral Processing Facilities (File # 347). 4/5/89.

¹⁷ Ibid.

¹⁸ EPA Region 6. 1984. Potential Hazardous Waste Site - Site Inspection Report. 9/5/84.

¹⁹ Ormet. 1983. Letter from F.G. Sikes to 1) M.O. Knudson, EPA Region 6 Water Management Division; and 2) J.D. Givens, LADNR Water Pollution Control Division, Re: None (pH excursions on 5/23 and 5/24/83). 6/2/83.

²⁰ Ormet. 1985. Letter from F.G. Sikes to G. Aydele, Office of Water Resources, LADEQ, Re: None (Ormet's progress toward ameliorating conditions in Panama Canal). 12/20/85.

²¹ Ormet. 1971. Map of Waste Water Discharge into Panama Canal, Burnside, LA. 5/11/71.

²² Ormet. 1986. Letter from F.D. Sikes to K. Huffman, EPA Region 6 Industrial Permits Section, Re: NPDES Permit No. LA0005606. 6/9/86.

²³ Ormet. 1983. Letter from F.G. Sikes to 1) M.O. Knudson, EPA Region 6 Water Management Division; and 2) J.D. Givens, LADNR Water Pollution Control Division, Re: None (pH excursions on 5/23 and 5/24/83). 6/2/83.

²⁴ Ormet. 1986. Letter from F.D. Sikes to K. Huffman, EPA Region 6 Industrial Permits Section, Re: NPDES Permit No. LA0005606. 6/9/86.

²⁵ Ormet. 1985. Letter from F.G. Sikes to G. Aydele, Office of Water Resources, LADEQ, Re: None (Ormet's progress toward ameliorating conditions in Panama Canal). 12/20/85.

²⁶ Louisiana Department of Natural Resources. 1985. Division of Water Pollution Control Complaint Form, Re: Discharges from Ormet Corp. 2/8/85.

²⁷ Ormet. 1986. Letter from F.D. Sikes to K. Huffman, EPA Region 6 Industrial Permits Section, Re: NPDES Permit No. LA0005606. 6/9/86.

LADEQ to conclude that the problem was primarily aesthetic, and no formal action was taken.²⁸ However, LADEQ did contact Ormet about "ameliorating the conditions in the Panama Canal."²⁹

In 1987, LADEQ's Ground Water Protection Division expressed concern that Ormet's proposal to close the red mud impoundments in their present condition would allow production of leachate and possible ground-water contamination. LADEQ also suggested continued ground-water monitoring as a part of closure.³⁰ Ground-water monitoring data were not found in the documents reviewed.

3.3.3 Findings Concerning the Hazards of Red muds

Potential danger from red muds is low primarily because the intrinsic hazard of the waste due to the presence of toxic constituents is relatively low. Specifically, the waste does not exhibit any characteristics of hazardous waste (see 40 CFR 261) and only arsenic and chromium are present in sufficient concentrations in the mud solids that could conceivably pose a cancer risk greater than 10^{-5} under conservative ("worst case") exposure scenarios (i.e., routine incidental ingestion of the muds, inhalation of airborne particulate concentrations at the National Ambient Air Quality Standard). The radium-226 concentration is approximately equal to EPA's standard for the cleanup of inactive uranium mill tailings sites, indicating a minor potential for radiation risk if the material were used in home construction (which it is not), or if the mud lakes after closure are allowed to be used in an unrestricted manner. Given current management practices, these exposure scenarios are unlikely. After closure, however, direct access to the muds should be restricted and dust could be a problem at some facilities due to the small particle size of the material and the relatively arid setting of some facilities.

Available laboratory (EP) leachate data indicate that only arsenic (in two out of four samples from two out of three facilities sampled) and selenium (in one sample) are present in leachate from the muds at concentrations that exceed the conservative screening criteria by a narrow margin (a factor of three). Qualitative review of the potential for transport and exposure in ground and surface water indicates that the potential exists at several facilities for mud contaminants to migrate into the environment; however, the migration is not expected to cause significant health or environmental impacts for the reasons stated above. In addition, it is likely that actual leachate concentrations are lower than the laboratory leachate considered here because the EP leaching procedure may overestimate leachate concentrations due to the use of an acidic leaching solution for what is a very alkaline waste material.

The finding that the potential for danger to health and the environment is generally low is consistent with the fact that only very limited documented damages were identified. No documented damages to ground water associated with red muds were identified. At one facility, emergency surface water discharges with a pH > 9 from red mud lakes have occurred as the result of a storm event.

²⁸ Louisiana Department of Environmental Quality (LADEQ). 1985. Letter from P.L. Norton, Office of Water Resources, to W.A. Fontenot, LA Dept. of Justice, Lands and Natural Resources Division, Re: None (Red water complaint in the Panama Canal). 3/28/85.

²⁹ LADEQ. 1985. Letter from G.R. Aydelell, Office of Water Resources, to F.G. Sikes, Ormet Corp., Re: None (red color imparted to Panama Canal). 6/27/85.

³⁰ LADEQ. 1987. Office of Solid and Hazardous Waste, Memorandum from G.H. Cramer to P. Miller, Solid Waste Division, Re: Comments Concerning Ormet Closure GD-005-1484, Ascension Parish. 10/28/87.

3.4 Existing Federal and State Waste Management Controls

3.4.1 Federal Regulation

Under the Clean Water Act, EPA has the responsibility for setting "effluent limitations," based on the performance capability of treatment technologies. These "technology based limitations" which provide the basis for minimum requirements of NPDES permits, must be established for various classes of industrial discharges, which include a number of ore processing categories.

Permits for mineral processing facilities may require compliance with effluent guidelines based on best practicable control technology currently available (BPT) or best available technology economically achievable (BAT). BPT and BAT requirements for bauxite refining specify that there shall be no discharge of process wastewater pollutants to navigable waters (40 CFR 421.10-16), except that discharge is permitted in months in which precipitation exceeds evaporation. Wastewater quality limits for such discharges are not established by the regulations. In the case of States which have not been delegated authority by EPA to manage the NPDES program, such as Texas and Louisiana, EPA includes permit limits necessary to achieve State water quality standards for the effluent discharges.

EPA is unaware of any other specific Federal management control or pollutant release requirements that apply specifically to bauxite red mud wastes.

3.4.2 State Regulation

The five facilities in the alumina sector are located in Arkansas, Louisiana, and Texas. Two of these states, Louisiana and Texas, were chosen for regulatory review for the purposes of this report (see Chapter 2 for a discussion of the methodology used to select states for detailed regulatory study). Both of the study states exclude mineral processing wastes from hazardous waste regulation, classify red muds from alumina production as industrial solid wastes, and have air quality regulations or standards that apply to red mud management and disposal activities.

Of the two study states, Louisiana appears to be most comprehensive in its coverage of red muds from alumina production. Although no requirements have been drafted specifically for red mud impoundments, facility owner/operators must comply with general solid waste disposal provisions for soils (e.g., stability, permeability), hydrologic characteristics, precipitation run-on and run-off, location standards, security, safety, and waste characterization. Moreover, both alumina facilities in Louisiana maintain surface impoundment permits for their red mud impoundments, and must meet general industrial waste surface impoundment requirements such as run-on controls, liner requirements, design standards (e.g., to prevent overtopping and minimize erosion), waste characterization, and ground-water monitoring requirements. Surface impoundments must be dewatered and clean-closed (i.e., all residuals removed) or closed according to solid waste landfill closure provisions. Louisiana also requires that owners/operators of all industrial solid waste landfills and surface impoundments maintain financial responsibility for the closure and post-closure care of those waste units. Although Louisiana does not have an approved NPDES program, the state does require state permits for the discharge of leachate or run-off to surface waters. Finally, Louisiana air regulations require that its alumina processing facilities manage their wastes in a manner necessary to minimize fugitive dust emissions.

As with Louisiana, Texas classifies mineral processing wastes, including red muds from the production of alumina, as industrial solid wastes. Because both alumina facilities in Texas dispose of their wastes on property that is both within 50 miles of the respective facility and controlled by the facility owner/operator, the state has not required either facility to obtain a solid waste disposal permit. Both facilities have notified the state of their waste disposal activities. Facilities discharging to surface water must obtain both Federal NPDES and Texas water quality permits. According to Texas officials, the Reynolds alumina facility does not discharge to surface water and thus does not maintain a NPDES or state discharge permit. Finally, Texas officials noted past problems with fugitive dust emissions from the red mud disposal units at both facilities and indicated that enforcement actions have been taken against the

Reynolds facility. The Reynolds facility now uses a flooding process to keep the muds completely under water, while the Alcoa facility places coarse river sand over red mud areas that become dry in order to control emissions.

In summary, the alumina sector states studied in detail for this report, Louisiana and Texas, classify and regulate red muds from the production of alumina as industrial solid wastes. Of the two states, Louisiana has been more comprehensive in the kinds of environmental controls imposed on the management and disposal of these red muds under their solid waste authorities. Both Louisiana and Texas also require State water quality permits for discharges to surface water, in addition to Federal NPDES requirements, and have air quality regulations that address fugitive dust emissions. Texas in particular has had problems with fugitive dust emissions at both of its alumina facilities and has taken action in order to ensure that such emissions are controlled.

3.5 Waste Management Alternatives and Potential Utilization

As noted above, the available data indicate that red muds do not exhibit any of the characteristics of hazardous waste. Consequently, the issue of how alumina producers might modify their operations or waste management practices or be stimulated to develop alternative uses for red muds in response to prospective hazardous waste regulation is moot. Nevertheless, this section provides a brief summary of current red mud waste management practices and potential areas of utilization.

Responses by bauxite processors nationwide to the SWMPF Survey indicate that none of the red mud was sold or used for commercial purposes in the United States in 1988. Although red muds are not currently being utilized efforts have been made to find commercial uses for these residues. Several processes have been developed to recover iron from the red mud residues,^{31,32} and the potential exists to use red muds as a raw material in the iron and steel industry.³³ Alumina and titanium dioxide recovery from bauxite muds is also technically feasible, as well as recovery of other rare metals such as gallium, vanadium, and scandium.³⁴ Processing for recovery of metals other than iron, however, is not economically viable at present.

In addition to metal recovery, other methods of potential utilization of bauxite muds include use in making construction blocks, bricks, portland cement, in lightweight aggregate to make concrete, in plastic and resin as filler, pigments, and applications in making ceramic products.^{35,36,37} Research has also been conducted on the potential use of red muds as a reagent in various proposed waste treatment processes.^{38,39}

³¹ Parekh, B.K. and W.M. Goldberger. Utilization of Bayer Process Muds: Problems and Possibilities. Proceedings of the Sixth Mineral Waste Utilization Symposium, Chicago, IL, ed. Eugene Aleshin, 2-3 May 1978, pp. 123-132.

³² Shamsuddin, M. Metal Recovery from Scrap and Waste. Journal of Metals, February, 1986, pp. 29-30.

³³ Steel from Aluminum Waste: The Grate Electric Process Using "Red Mud" as Iron Ore, Heat Engineering, April/June 49:2, 1979, p. 23.

³⁴ Parekh, B.K. and W.M. Goldberger, op. cit., pp. 123-124.

³⁵ Parekh, B.K. and W.M. Goldberger. Utilization of Bayer Process Muds: Problems and Possibilities. Proceedings of the Sixth Mineral Waste Utilization Symposium, Chicago, IL, ed. Eugene Aleshin, 2-3 May 1978, pp. 123-132.

³⁶ Miller, R.H. and R.J. Collins. Waste Material as Potential Replacements for Highway Aggregates. National Cooperative Highway Research Program Report 166, 1976, p. 50.

³⁷ Thokur, R.S. and B.R. Sant. Utilization of Red Mud: Part I - Analysis and Utilization as Raw Material for Adsorbents, Building Materials, Catalysts, Fillers, Paints and Pigments. Journal of Scientific and Industrial Research, Vol. 42, February 1983, pp. 101-105.

³⁸ Parekh, and Goldberger, op. cit.,

³⁹ Thokur, and Sant, op. cit.,

3.6 Cost and Economic Impacts

Because the available data indicate that red muds do not exhibit any of the characteristics of hazardous waste, the issues of how waste management costs might change because of new requirements associated with hazardous waste regulation under RCRA Subtitle C and what impacts such costs might impose upon affected facilities are not meaningful. Consequently, no incremental costs or associated economic impacts would result from a decision to remove red muds from the Mining Waste Exclusion.

3.7 Summary

As discussed in Chapter 2, EPA developed a step-wise process for considering the information collected in response to the RCRA §8002(p) study factors. This process has enabled the Agency to condense the information presented in the previous six sections of this chapter into three basic categories. For the special waste in question (red muds), these categories address the following three major topics: (1) potential for and documented danger to human health and the environment; (2) the need for and desirability of additional regulation; and (3) the costs and impacts of potential Subtitle C regulation.

Potential and Documented Danger to Human Health and the Environment

The intrinsic hazard of red muds is relatively low compared to the other mineral processing wastes studied in this report. The muds do not exhibit any of the four characteristics of hazardous waste, and only chromium was detected in the muds in a concentration that exceeds the risk screening criteria used in this analysis by a factor of 10. The concentration of radium-226 in the muds approximately equals EPA's standard for the cleanup of inactive uranium mill tailings sites, indicating a slight potential for radiation risk if the muds were used in home construction (which they are not), or if the mud lakes after closure were allowed to be used in an unrestricted manner. In addition, the alkaline nature (i.e., high pH) of the muds is expected to limit plant growth on the dried, closed impoundments.

Based on an examination of the existing conditions at the five active bauxite refining facilities, EPA concludes that the management of red muds may allow contaminants to migrate into the environment, but that the potential for significant exposure to these contaminants is low. Specifically:

- There is a potential for contaminants to migrate into shallow ground water because the muds are managed in impoundments and are submerged below liquids that may drive contaminants to the subsurface, the bases of most impoundments used to manage the muds extend beneath the water table, and only two impoundments are equipped with leachate collection systems. However, useable ground water at each site is considerably deeper (and thus more protected) and the concentration of any released contaminants is expected to be below levels of concern at possible downgradient exposure points.
- It is also possible for contaminants from the impoundments to migrate into nearby surface waters at three facilities that are within 60 meters of a water body. However, this migration is not expected to cause significant impacts because the potential receiving water bodies have a moderate to large assimilative capacity and resulting contaminant concentrations are likely to be well below human health and ecological protection benchmarks.
- When the impoundments have closed and the muds have dried, there is also a potential for fine particles of the mud to be blown into the air as dust. Considering the distances to existing residences and the low concentrations of contaminants in the muds, however, airborne concentrations at the residences are likely to be below levels of concern.

The finding that the potential for danger to human health and the environment is low is consistent with the fact that only one very limited documented damage case attributable to the muds has been identified. State and EPA Regional files were reviewed in an effort to document the performance of red mud management practices at the five active bauxite facilities and at one inactive facility. No documented damages to ground water associated with red muds were

identified. At one facility, emergency surface water discharges with a pH > 9 from the red mud lakes have occurred as the result of storm events. This type of discharge is already regulated under the NPDES program.

Likelihood That Existing Risks/Impacts Will Continue in the Absence of Subtitle C Regulation

As summarized above, the current red mud management practices and environmental conditions at the five active bauxite facilities may allow some contaminant migration into ground water, surface water, and air, both now and in the future. However, given the generally low concentrations of contaminants in the muds, this migration should not pose a serious human health and environmental threat under reasonable mismanagement scenarios. EPA believes that, after the impoundments have been closed, direct access to the muds should be restricted to avoid radiation hazards and risks. Furthermore, it would be prudent to control fugitive dust emissions from dried or closed impoundments, especially at the facilities located in arid settings, because the dried muds are susceptible to wind erosion and inhalation exposures conceivably could occur if people moved close to inactive impoundments in the future.

EPA believes that the low-risk conclusion for the five active bauxite facilities accurately reflects future conditions because the muds are not likely to be generated and managed at alternate sites. In addition, the quantity of the muds is so large that it is unlikely that the muds will be dredged from the impoundments in which they settle and disposed of elsewhere. Current industry trends also indicate that construction of new bauxite refining facilities in the U.S. is not likely. In addition, the muds historically have not been used off-site extensively. Although a variety of approaches to utilization of the muds have been researched, including use in making construction blocks, bricks, and portland cement, and recovery of iron and other metals, none of these alternatives appear economically viable at present or in the foreseeable future.

The extent of state regulation of red muds appears to be commensurate with the risks posed by this waste. The five active facilities are located in Louisiana, Texas, and Arkansas, of which Louisiana and Texas were studied in detail for purposes of this report. Both Louisiana and Texas exclude mineral processing wastes from hazardous waste regulation and classify red muds generated by alumina production as industrial solid wastes. Although Louisiana's regulations do not contain provisions tailored specifically to red muds, the state does apply surface impoundment and landfill closure and financial responsibility requirements to the muds in a fairly extensive manner. Texas has established standards for all aspects of the control of industrial solid waste. Nevertheless, neither of the two facilities in Texas are required to obtain a permit, because both dispose of their wastes on property owned or controlled by the facility owner/operator, and thus are only subject to notification requirements. Both Louisiana and Texas require State wastewater discharge permits in addition to Federal NPDES permits, and both states address fugitive dust emissions in the air permits issued to the alumina facilities within their jurisdictions.

Costs and Impacts of Subtitle C Regulation

Because of the low risk potential of red muds, the general absence of documented damages associated with these materials, and the fact that this material does not exhibit any characteristics of hazardous waste, EPA has not estimated the costs and associated impacts of regulating red muds from bauxite refining under RCRA Subtitle C.